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Case Number: T 0893/14 - 3.4.03

Application Number: 08013467.9

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Language of the proceedings: EN

Title of invention:
Barrier layers in inverted metamorphic multijunction solar cells

Patent Proprietor:
SolAero Technologies Corp.

Opponent:
AZUR SPACE Solar Power GmbH

Headword:

Relevant legal provisions:
EPC Art. 56

Keyword:
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Catchword:

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Case Number: T 0893/14 - 3.4.03

D E C I S I O N
of Technical Board of Appeal 3.4.03
of 6 September 2018

Appellant: (Opponent)	AZUR SPACE Solar Power GmbH Theresienstrasse 2 74072 Heilbronn (DE)
Representative:	Koch, Bertram Koch Müller Patentanwaltsgesellschaft mbH Maaßstraße 32/1 69123 Heidelberg (DE)
Respondent: (Patent Proprietor)	SolAero Technologies Corp. 10420 Research Road SE Albuquerque, NM 87123 (US)
Representative:	Maucher Jenkins Patent- und Rechtsanwälte Liebigstrasse 39 80538 München (DE)
Decision under appeal:	**Interlocutory decision of the Opposition Division of the European Patent Office posted on 7 March 2014 concerning maintenance of the European Patent No. 2148378 in amended form.**

Composition of the Board:

Chairman	G. Eliasson
Members:	M. Stenger
	W. Van der Eijk

Summary of Facts and Submissions

I. The appeal of the opponent concerns the interlocutory decision of the Opposition Division to maintain the European patent No. EP2148378 in amended form.

II. At the end of the oral proceedings before the Board, the appellant/opponent requested the revocation of the patent in its entirety.

III. At the end of the oral proceedings before the Board, the proprietor/respondent requested to maintain the patent in the form filed as auxiliary request with letter dated 6 August 2018.

IV. The following documents will be referred to in this decision:
D2: US 2007/277873 A1
D3: WO 2004/022820 A1

V. The wording of claim 1 of the only request is as follows (feature labeling M1, M2, ... added by the Board and generally corresponding to the labeling introduced by the opponent in the grounds of appeal):

M1 *A method of forming a multijunction solar cell comprising*

M2 *an upper subcell (C),*

M3 *a middle subcell (B),*

M4 *and a lower subcell (A),*

M5 *the method comprising in the following order:*

M6 *providing first substrate (101) for the epitaxial growth of semiconductor material;*

M7 *forming a first solar subcell (A) on said substrate having a first band gap;*

M8 *forming a second solar subcell (B) over said first solar subcell (A) having a second band gap smaller than said first band gap;*

M9 *forming a first barrier layer (116a) over said second subcell (B);*

M10 *forming a stepped grading interlayer (116) composed of InGaAlAs over said barrier layer (116a),*

M11 *said grading interlayer (116) having a third band gap greater than said second band gap;*

M12 *forming a second barrier layer (116b) over said grading interlayer (116); and*

M13 *forming a third solar subcell (C) over said grading interlayer (116)*

M14 *having a fourth band gap smaller than said second band gap such that said third subcell (C) is lattice mismatched with respect to said second subcell (B);*

characterized in that

M15 *said second (116b) barrier layers is composed of any As, P, N, or Sb based III-V compound semiconductors*

M16 *with said second barrier layer (116b) having a different composition than that of said first barrier layer (116a); and*

M17 *said first (116a) and second (116b) barrier layers are composed of suitable material, thickness and lattice constant to prevent threading dislocations from propagating,*

M18 *said first barrier layer being composed of InGa(Al)P.*

VI. In this decision, two sub-features M17a and M17b which when combined correspond to feature M17 will be used for ease of reference as follows (in accordance with the labeling in the grounds of appeal):

M17a *said first (116a) barrier layer is composed of suitable material, thickness and lattice constant to prevent threading dislocations from propagating,*

M17b *said second (116b) barrier layer is composed of suitable material, thickness and lattice constant to prevent threading dislocations from propagating,*

VII. The arguments of the proprietor, as far as they are relevant to the present decision, may be summarised as follows:

(a) The invention differed by two key distinctions from D2.
The first was the presence of a sandwich structure consisting of a first barrier layer, a graded layer and a second layer. The second key distinction concerned the material or composition of the first barrier layer.

These distinctions had the technical effect of preventing threading dislocations from propagating into the subcells and thus solved the objective technical problem of increasing the yield or efficiency of the multijunction solar cell.

(b) Concerning the first key distinction, no sandwich structure was disclosed in any of the available documents. Further, starting from D2 and applying the teaching of D3, the skilled person would possibly arrange a barrier layer on top of the graded layer. He would not, however, arrive at a sandwich structure also involving a lower or first barrier layer, since D3 did not disclose any such layer.

(c) Relating to the second key distinction, it should be assessed what the skilled person *would* do and not what he *could* do according to the problem solution approach in order to avoid speculation.

(i) The skilled person would not be led by the teaching of D3 to change the composition of the buffer layer 115a of D2 to InGa(Al)P since this material was not disclosed in D3.

(ii) Providing a phosphorus based barrier layer in combination with arsenic based graded layers was done according to the invention only because the inventors had realised that thereby, backward propagation of threading dislocations was prevented.

(iii) In D2, the graded layer 116 and the buffer layer 115a were both made of InGaAs-type material and in D3, the graded region 14 and the intermediate region 16 were also

made of materials corresponding to each other. Based on D2 and D3, it would thus be counter-intuitive for the skilled person to provide a barrier layer made of a different type of material than the graded layer as defined in the invention.
More specifically, changing from a phosphorus based layer to an arsenic based layer made the manufacturing method more complex, since it had to be made sure that all the phosphorus was removed before starting deposition of the arsenic based graded layer. Thus, the skilled person, starting from D2, would not change the composition of the buffer layer 115a to a phosphorus based material because he would consider the buffer layer 115a in the context of its neighbouring arsenic based layers and not in isolation.

VIII. The arguments of the opponent, as far as they are relevant for the present decision, can be summarised as follows:

(a) Claim 1 differed from D2 by features M12, M15, M16, M17b and M18. These differentiating features solved the objective technical problem of improving the properties of the electronic device, i.e. the properties of the multijunction solar cell of D2.

(b) Second barrier layer
D3 was concerned with the solution of this problem and suggested to prevent threading dislocations from propagating by introducing a barrier layer called intermediate layer between a graded region and the active layer. The teaching of D3 was

independent of the specific compositions of the example disclosed and amounted to a generally valid concept. The skilled person would thus be prompted to add a second barrier layer on top of the graded layer in D2.

(c) Composition of the first barrier layer

(i) The only requirements relevant for the buffer layer 115a of D2 in relation to its neighbouring layers were that the band gap and the lattice constant should be chosen in an appropriate manner. The skilled person would thus predominantly consider these properties.
D3 taught that such band gap and lattice constant requirements could be met by a combination of arsenic based and phosphorous based layers. Since subcell B in D2 was arsenic based, D3 taught the skilled person that the buffer layer 115a could be changed to a phosphorous based layer.

(ii) The use of InGa(Al)P for the first barrier layer was not presented in the patent opposed as providing any particular technical effect as compared to using any other As, P, N or Sb based III-V compound semiconductor (sentence bridging pages 13 and 14 and last paragraph on page 16 of the grounds for appeal).

(iii) Providing neighbouring layers of different compositions was a routine task for the person skilled in semiconductor layer deposition. For example, D2 disclosed a graded layer that consisted of a different material (a quaternary material including

aluminium) than the buffer/barrier layer 115a (tertiary material, without aluminium).
More specifically, switching during the deposition process from a phosphorus based layer to a neighbouring arsenic based layer did not represent any particular difficulty. Switching to aluminium was slightly more difficult.
Generally, changing the layer composition was possible using the MOVPE technology with very thin transition layers.

Reasons for the Decision

1. State of the art

1.1 D2

Document D2 discloses a method of forming an inverted metaphoric multijunction solar cell, formed by combinations of group III to group V elements and including three subcells A, B and C as well as a step-graded series of layers, i.e. of layers with step-wise changing chemical compositions, arranged between lattice-mismatched subcells B and C (see abstract, figure 1, [36] and [37]). A buffer layer 115a is arranged between the middle subcell B and the step-graded layers.

1.2 D3

Document D3 relates to a method of eliminating strain and dislocations in lattice-mismatched heteroepitaxial systems involving a step-graded region to obtain active layers of good quality (see abstract).

2. Inventive step

2.1 Closest state of the art

Both parties consented that D2 represents the closest prior art. Since D2 relates, just like the patent opposed, to inverted metamorphic multijunction solar cells and discloses most of the features of claim 1 of the only request, the Board sees no reason to disagree.

2.2 Claim 1 compared to D2

None of the parties disputed that D2 discloses features M1 to M8, M11, M13 and M14 (see figure 1 and [36] to [45] of D2). The reference numerals of these features used in the patent opposed are identical to the ones used in D2.

D2 further discloses a buffer layer 115a formed between the second subcell B and a step graded layer 116. Both the thickness and the preferred composition of this buffer layer (1 micrometer of InGaAs, see [44] of D2) correspond to the requirements defined for the first barrier layer in the patent opposed (see [40] of the patent opposed).

Since the lattice constant of a layer is defined by its composition or material, the lattice constant of the buffer layer inevitably fulfills these requirements as well.

It must be concluded that the buffer layer 115a of D2 is composed of a material, thickness and lattice constant such that it is suitable to prevent threading dislocations from propagating to the same extent as the first barrier layer 116a of the patent opposed.

Thus, the *buffer layer 115a* of D2 corresponds to the *first barrier layer 116a* of the patent opposed in the sense of features M9 and M17a.

Further and as mentioned above, the preferred composition of the step graded layer 116 is InGaAlAs as required by feature M10 (see [44] of D2).

It follows from the above that D2 also discloses features M9, M10 and M17a. The proprietor neither disputed that finding in his latest written submission dated 6 August 2018 nor during oral proceedings before the Board.

2.3 Differences

In view of the above, the subject-matter of claim 1 thus differs from D2 by features M12, M15, M16, M17b and M18. This was not disputed during oral proceedings before the Board (see sections VII(a) and VIII(a) above).

Features M12, M15, M16 and M17b correspond to the first key distinction as defined by the proprietor and concern the second barrier layer. Feature M18 corresponds to the second key distinction as defined by the proprietor and relates to the first barrier layer.

2.4 Technical effect/objective technical problem

Both parties opined during oral proceedings before the Board that the differentiating features achieved the technical effect of reducing the propagation of threading dislocations.

Further, both parties concurred that the objective technical problem to be solved, starting from D2, should be formulated as how to improve the device quality, that is how to increase the efficiency or

yield of the solar cell disclosed in D2 (see sections VII.(a) and VIII.(a) above).

The Board sees no reason to disagree.

2.5 D3

Document D3 aims at preventing threading dislocations from propagating from a graded layer into an active region of a device (page 4, lines 18 to 21; page 10, lines 6 to 7 and page 12, lines 13 to 15 of D3; see also point 26 of the minutes of the first instance oral proceedings held on 7 March 2013).
According to D3, this optimises the quality of the active layer which is deposited above the graded region (page 1, lines 10 to 15), which is advantageous for complex multilayer heterostructures (page 4, lines 22 to 23).

Document D3 thereby aims at solving the objective technical problem as defined above. The skilled person would thus consult D3, as argued by the opponent (see section VIII.(b) above). This was not disputed by the proprietor.

2.6 Features M12, M15, M16 and M17b

In order to solve the objective technical problem as defined above, D3 suggests to provide a barrier layer (called *intermediate region*) on top of the grading layer (*step-graded layer* or *region*, see page 6, lines 3 to 14 and page 10, lines 6 to 7), as argued by the opponent (see section VIII.(b) above).

The Board accepts the argument of the proprietor (see section VII.(b) above) that neither D2 nor D3 per se discloses a graded layer sandwiched between two barrier layers. The Board also accepts that D3 does not

disclose a layer corresponding to the first barrier layer of claim 1.
However, by providing, as suggested by D3, a barrier layer/intermediate layer *on top* of the graded layer of D2, the skilled person would arrive at a graded layer sandwiched between the *buffer layer 115a* disclosed in D2 and the *intermediate layer 16* proposed by D3.
Thus, D3 suggests the integration of feature M12 into the device of D2.

The intermediate region suggested by D3 is made from a III-V semiconductor compound comprising both phosphorus and arsenic (see page 11, lines 13 to 15), whereby D3 equally suggests feature M15.

The addition of a barrier layer/intermediate layer on top of the grading interlayer in the device of D2 would inevitably require a composition of this added barrier layer differing from the composition of the (first barrier) layer 115a in view of the varying lattice constant of the intermediate grading interlayer. Thus, D3 also suggests feature M16.

Further, the thickness as well as the composition (and thereby the lattice constant) of the intermediate region of D3 are suitable to prevent threading dislocations from propagating, as explained in [40] of the patent opposed (see also section 2.2 above).
Moreover, D3 explicitly states that the intermediate region serves to prevent threading dislocations from reaching the active region, which is located above the intermediate region (page 1, lines 13 to 15). Thereby, D3 equally suggests feature M17b.

Thus, starting from D2, the skilled person would be incited by the teaching of D3 to integrate features M12, M15, M16 and M17b into the device disclosed in D2.

The Board notes that this corresponds to the conclusion of the Examining Division in section 2.5 of the contested decision.

2.7 Feature M18

The Board accepts that D3 does not disclose any InGa(Al)P layer, as argued by the proprietor (see section VII.(c)(i)). Thereby, D3 does not suggest to arrange a layer of that material under a step graded layer.

However, as mentioned above, D2 mentions InGaAs only as the *preferred* composition for the buffer layer 115a (see [44]). Concerning the general requirements, D2 explicitly states that *the multijunction solar cell structure* (that is, each and every one of its layers) *could be formed by any suitable combination of group III to V elements listed in the periodic table subject to lattice constant and band gap requirements* (see [37] of D2).
The skilled person reading D2 would thus readily consider *any combination* of the mentioned elements for the buffer layer 115a, including InGa(Al)P, without the exercise of an inventive step.

The Board further notes that substituting one group III or group V element by another in a layer made of a specific III-V semiconductor material in order to find an alternative to that specific III-V semiconductor material is a routine task for the skilled person. It involves only generally known changes in bandgap and

lattice constant (see also the submission of the opponent in section VIII.(c)(i) above).
The skilled person would thus, even without taking into account [37] of D2, readily consider to replace any of the elements In, Ga and As of the preferred composition InGaAs of the buffer layer 115a (see [44] of D2) totally or in part by other elements of the same group(s) without the exercise of an inventive activity. Thereby also, he would in a straightforward manner consider replacing As completely by P and In and Ga partially by Al.

The Board accepts that if there was a particular technical effect obtained by using a InGa(Al)P barrier layer as opposed to using a barrier layer consisting of any other group III-V semiconductor as submitted by the proprietor (see section VII.(c)(ii)), the choice of that particular barrier layer material could provide the basis for acknowledging the presence of an inventive step.
The Board notes that this reasoning corresponds to the argumentation of the Examining Division in section 3.2 of the contested decision.

However, as pointed out by the opponent (see section VIII.(c)(ii) above), using InGa(Al)P as material for the first layer is not presented in the patent opposed as achieving any such particular technical effect. Instead, the technical effect shown in Figure 18 is presented as being obtained in the presence of a barrier layer 116a made from *any* of the III-V compound semiconductors mentioned in paragraph 44 of the original application. Thereby, the data shown in figure 18 only show that it is more advantageous to have a barrier layer below a graded layer than none at all, but does not give any indication as to which

composition of that barrier layer would be particularly desirable.

The Board also accepts that using a phosphorus-containing composition for the buffer layer 115a of D2 in combination with a step graded layer not containing phosphorus might result in a slightly increased complexity of the manufacturing process in the sense as argued by the proprietor (see section VII.(c)(iii) above).

However, as pointed out by the opponent (see section VIII.(c)(iii)), it is quite common in semiconductor multilayers that from one layer to the next, the composition is changed involving only very thin transition layers. The Board is therefore of the opinion that changing the composition from one semiconductor layer to the other cannot be seen as representing any real burden to the skilled person.
For the case of As and P, this opinion is supported by D2 (which explicitly discloses depositing an arsenic-based base layer 113 on top of a phosphorous based emitter layer 112, see [43]) and by D3 (which discloses step-graded layers 14 that have a varying content of As and P from step to step, see page 11, lines 10 to 12). Therefore, the Board is of the opinion that the skilled person would accept a slightly more complex manufacturing process in exchange for obtaining a layer composition with the desired band gap and lattice constant.

Thus, substituting As in layer 115a of D2 by P and adding Al *would* be an obvious design choice for the skilled person in the context of III-V semiconductors not requiring the exercise of an inventive step, particularly in the light of [37] of D2.

2.8 To summarise, the skilled person would, starting from D2 and trying to solve the objective technical problem to improve the quality of the third subcell C, consider the teaching of D3 and thereby integrate features M12, M15, M16 and M17b into the multijunction solarcell of D2 without the exercise of an inventive step.

He would further consider all group III to group V elements as mentioned in D2 to form the buffer layer 115a, whereby the composition of the first barrier layer 116a as defined in feature M18 has to be considered as being an obvious design choice not involving an inventive step.

For these reasons, the subject-matter of claim 1 of the only request does not involve an inventive step according to Article 56 EPC.

3. The subject-matter of claim 1 of the only request on file is not inventive according to Article 56 EPC. Thus, the patent has to be revoked.

Order

For these reasons it is decided that:

1. The decision under appeal is set aside
2. The European patent No. 2148378 is revoked.

The Registrar: The Chairman:

S. Sánchez Chiquero G. Eliasson

Decision electronically authenticated